Climate Change Fuel Cell Program

First National Bank of Omaha
Applying Four 200 Kilowatt Fuel Cells in
a Mission Critical Installation

Final Report

Report on First Year Operating Experience
From May, 1999 to June 2000

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Disclaimer:

ABSTRACT

The First National Bank of Omaha is the nation's 7th-largest processor of VISA credit card transactions. Major customers such as "The Gap" chain of stores process all their VISA transactions through the bank's computers. The bank formerly relied on conventional UPS supported by battery banks to supply voltage during sags and short-term outages. Standby diesel generators supplied electricity during longer-term outages. Two failures in this system, each costing the bank and its customers millions of dollars, convinced the bank management that the traditional approach was not going to meet the critical power needs of their 200,000 square foot technology center already under construction.

A conventional data center UPS system only delivers electricity to computers, chillers and fans with 99.99% availability, at best. This report details an innovative fuel cell based system designed to provide the First National Bank of Omaha 99.9999% available power while providing economic benefit.

Combining four phosphoric acid PC25™ fuel cell power plants with motor generators and flywheels, this installation was the first of its kind in the world and continues to be unique in bringing “added value” to an end user to offset the high first costs of fuel cells. In addition to electricity, thermal energy is recovered from the fuel cells and is used in the facility.

A review of the information in this report will show that fuel cells can be used successfully in mission-critical high availability applications.

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EXECUTIVE SUMMARY

A fuel cell based high-availability electrical power system has been installed at the First National Bank of Omaha's new data processing technology center. This system was installed in response to a need for very clean, reliable power over a long period of time. The bank had had first hand experience with conventional UPS systems and was not satisfied with the status quo.

Although the initial capital investment for the fuel cell based system cost more than the alternative, a life cycle cost analysis proved that the fuel cells were a better investment over the life of the equipment.

In addition to providing an economic benefit to the bank this system protected the bank from the very negative impact of a power failure on the critical bus providing electricity to the banks computers. Data from this site has proven that fuel cell power plants can outperform traditional UPS systems in terms of system efficiency, low emissions and high reliability.

A review of the first years operating data has proven that fuel cells are suitable for use in high-availability mission critical applications. The critical bus at the bank has never experienced an outage or any voltage fluctuation outside the national standard (IEEE446-1987). Maintenance and operational costs have all been within the initial assumption parameters.

The fuel cell installation at the First National Bank of Omaha had received a lot of interest from both local and national news media. Information on this project has been presented numerous times in articles, conferences and seminars. Given the success of this project it is expected that similar high-availability mission critical applications will follow in the near future.

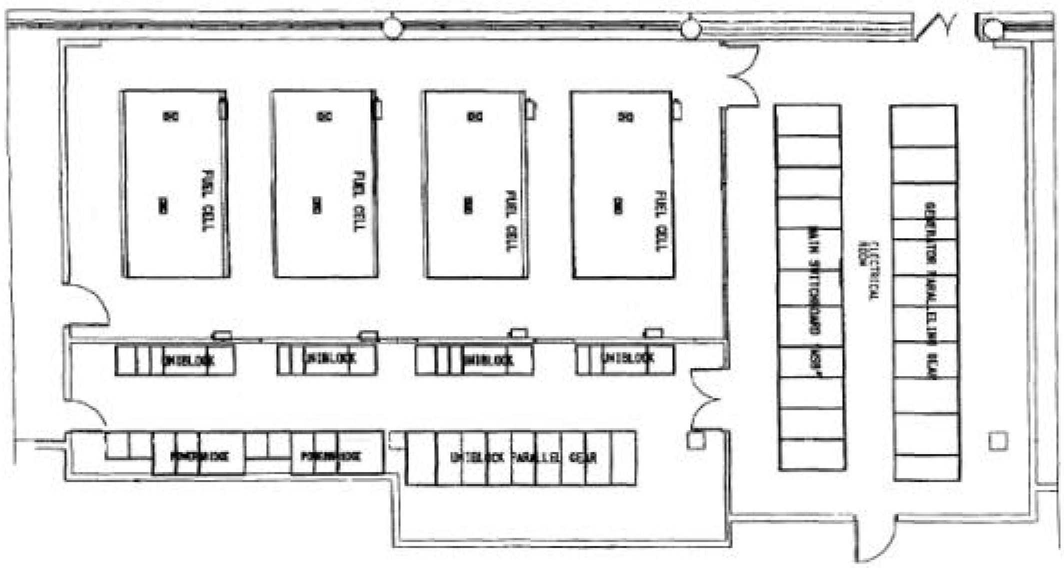
INTRODUCTION

In May 1999 the first fuel cell based high-availability system began operating at the newly constructed First National Technology Center in Omaha, Nebraska. The Technology Center houses the credit card and banking transaction data processing center for the First National Bank of Omaha (FNBO). Since installation, this 800 kW System has been supplying computer-grade electricity without interruption.

An independent analysis of the high-availability system design for the First National Technology Center determined that the system achieves availability greater than 99.9999% measured against independent failures[1]. A firm of consulting scientists and engineers specializing in probabilistic risk assessment (PRA) performed the analysis.

The analysis concluded that the overall system "Unavailability," that is, potential downtime, caused by independent failures was less than 10^{-6}. The system Mean Time To Failure (MTTF) calculated to be in excess of 100 million hours. The calculations used a 16-hour Mean Time to Repair. Component, as opposed to system, MTTF ranged from less than 500 hours to more than 100,000 hours. The analysis employed standard PRA techniques and a combination of public and private databases for failure rate and repair data. In particular, extravagant vendor claims for component MTTF in excess of 100 years were heavily discounted, generally by a factor of 10, unless substantive supporting documentation was provided to support the claim. The system design tolerates all credible and incredible component failures, maintenance, and repairs without impact to the critical loads.

Start-up of the system at the First National Technology Center was completed in April of 1999 and the system went online May 1, 1999. Over the next two months a small number of insignificant parts (such as a modem in a motor generator and a circuit board in a fuel cell) failed within various system components. Manufacturing defects caused these failures and at no time did their failure cause an interruption of power on the critical bus. Since the commissioning at the First National Technology Center the system has not experienced a system shutdown. Although individual components have been down for scheduled or unscheduled maintenance, voltage on the critical bus to the main computer floor has never been interrupted.



The system at Omaha has experience a plethora of unanticipated events. Natural gas service to the system was interrupted when the local utility filled one of the two redundant gas mains with air during an improper repair procedure. Lack of fuel caused all four fuel cell power plants to simultaneously shut down. Critical loads were not affected (or even aware of the problem) as the system switched to secondary backup sources without incident. This event demonstrates the extreme robustness and fault tolerance of the complete system.

Enhancements to the FNBO system software were made in October 1999 and again in December 2000. Annual maintenance was performed in November of 1999.

MEAN TIME BETWEEN FAILURE AND RELIABILITY

Individual Fuel Cell Operation

Fuel Cell Serial Number 9100

During the first twelve months of operation the longest continuous run for fuel cell SN9100 was 2,280 hours. The SN9100 event log for this period included:

DATE	EVENT
September 6, 1999	Replaced quad power supply
September 16, 1999	Large amount of air in natural gas supply caused shutdown
October 31, 1999	Power Plant down for annual maintenance, restarted on November 4, 1999
November 18, 1999	SHUTDOWN - water leak, repaired and restarted
February 8, 2000	Replaced controller
April 23, 2000	Replaced Inverter drawer

For the period from March 24, 1999 through February 28, 2001 (23 months) fuel cell SN9100 operated for 15,887 hours and delivered 2,427 MWhrs of electricity. For this period the availability was 93.72%. The mean time between forced outages was 2,270 hours.

Fuel Cell Serial Number 9102

During the first twelve months of operation the longest continuous run for fuel cell SN9102 was 3,426 hours. The SN9102 event log for this period included:

July 19, 1999	Replaced Steam Ejector (ZT010)
July 21, 1999	Replaced Inverter Drawer 2
September 16, 1999	Large amount of air in natural gas supply caused shutdown
November 7, 1999	Power plant down for annual maintenance, restarted on Nov. 9, 1999
February 24, 2000	Pump 450 replaced

For the period from March 24, 1999 through February 28, 2001 (23 months) fuel cell SN9102 operated for 15,879 hours and delivered 2,508 MWhrs of electricity. For this period the availability was 93.56%. The mean time between forced outages was 3,176 hours.

Fuel Cell Serial Number 9116

During the first twelve months of operation the longest continuous run for fuel cell SN9116 was 3,504 hours. The SN9116 event log for this period included:

May 25, 1999	New power plant controller software installed
June 15, 1999	UPS Failure, replace one of the battery packs and unit restarted
June 17, 1999	Installed new PCS controller card
June 20, 1999	Replaced controller
June 29, 1999	Replaced two battery packs in UPS
June 30, 1999	Replaced heater 400 (HTR400)

July 8, 1999	Replaced inverter power supplies
July 13, 1999	Replaced a controller card
July 13, 1999	Upgraded fuel cell operating software to version 4.09
July 29, 1999	Replaced air flow switch (fan 165)
September 16, 1999	Large amount of air in natural gas supply caused shutdown
September 30, 1999	Resin bottle incorrectly installed in fuel cell - SHUTDOWN, corrected and restarted same day
October 2, 1999	Pump 451 failed, SHUTDOWN - replaced and restarted
November 10, 1999	Power plant down for annual maintenance, restarted on Nov. 12, 1999
November 30, 1999	Relay interface card (FC14428-02)
March 31, 2000	Replaced fuse and Digital Output Module
April 27, 2000	Air conditioner replaced
April 28, 2000	Thermostat on air conditioner replaced

For the period from March 24, 1999 through February 28, 2001 (23 months) fuel cell SN9116 operated for 14,752 hours and delivered 2,327 MWhrs of electricity. For this period the availability was 86.94%. The mean time between forced outages was 868 hours.

Fuel Cell Serial Number 9148

During the first twelve months of operation the longest continuous run for fuel cell SN9148 was 3,960 hours. The SN9148 event log for this period included:

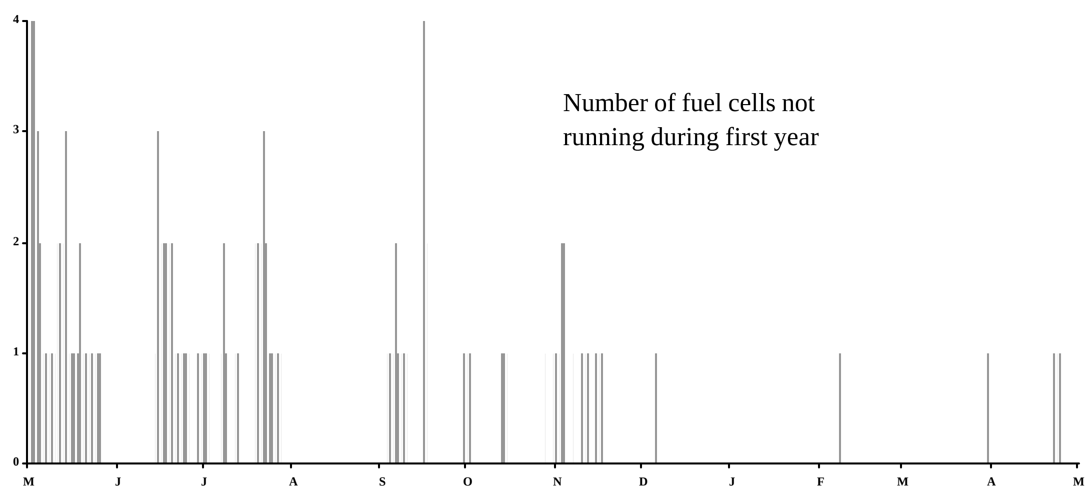
May 26, 1999	Replace natural gas orifices change out
June 19, 1999	Installed new software v.4.07 and replace two heaters (HTR002)
September 5, 1999	Replaced controller
September 16, 1999	Large amount of air in natural gas supply caused shutdown
October 15, 1999	Pump 400 failed, SHUTDOWN, replaced and unit restarted
October 28, 1999	Power plant tripped when Radar laptop computer was connected
November 14, 1999	Power plant down for annual maintenance, restarted on Nov. 16, 1999
May 1, 2000	SHUTDOWN - clogged air filter 100

For the period from March 24, 1999 through February 28, 2001 (23 months) fuel cell SN9148 operated for 15,735 hours and delivered 2,474 MWhrs of electricity. For this period the availability was 92.94%. The mean time between forced outages was 2,623 hours.

Combined Fuel Cell Operation

The fuel cell installation at the First National Bank of Omaha is first and foremost a high-availability system. It was designed to replace a conventional UPS system and to provide 99.9999% electrical availability to the banks computers. Mean time Between Failures (MTBF) and Mean Time to Repair (MTTR) were critical to achieving this level of availability. An independent analysis using probabilistic risk analysis techniques concluded the delivered availability level for the system was 99.99997%. This analysis only looked at the total system performance, individual fuel cell availability was not analyzed.

The analysis of the high-availability system was based on a critical load at the First National Bank of Omaha of 320 kilowatts. The four fuel cells are capable of generating 800 kilowatts at rated power. Only two fuel cells are needed at any time to meet the needs of the critical bus. During the first year of operation two or more fuel cells were operating together for 97.8% of the time. For the small amount of time when three or four fuel cells were shut down at the same time the utility electric grid was utilized as backup.



On September 16, 1999 a repair crew from the local natural gas utility mistakenly introduced a large amount of air into the natural gas main pipeline adjacent to the First National Bank of Omaha. When this air reached the fuel cells all four units shutdown. The electric utility seamlessly picked up the electrical loads in the building and the employees of the bank were unaware of any problem. Based on Probabilistic Risk Analysis the system is more likely to fail due to common-cause failure mechanisms such as human error than due to component failure.

COST BENEFIT

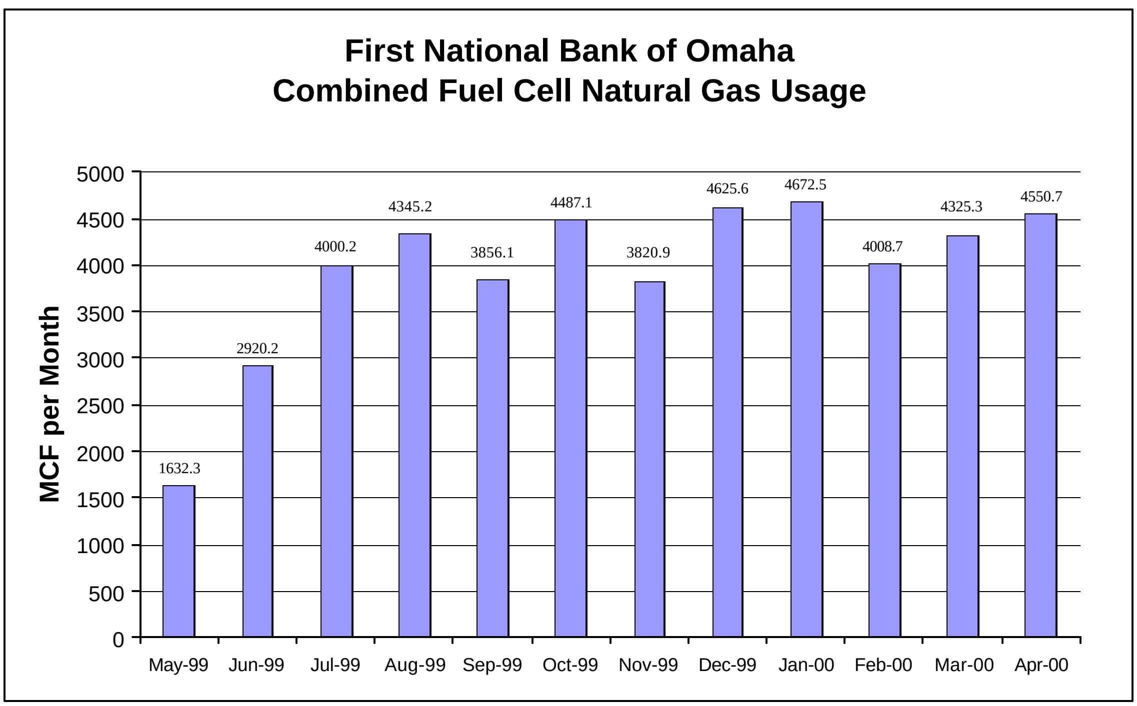
A life cycle costs analysis performed by the First National Bank of Omaha confirmed that over the 20-year life cycle of the project the fuel cell installation was more cost effective than the traditional parallel, redundant UPS system alternative.[2]

The UPS consumes 344 Kw of electricity to deliver 320 Kw of critical computer power. This inefficiency also generates a heat load, which costs approximately $8,000 to remove from the conditioned UPS environment, plus an additional $20,000 annually to condition this space. An additional 420 Kw of electricity is purchased from the utility to provide the same 740 Kw of electrical load as the fuel cell system. Another 740 Kw of demand charges also are included for the UPS system, while an additional 200 Kw is required to equal the heat energy produced by the fuel cell system. Annual operating costs for the UPS, including installation, average about $640,000 per year. A 20-year life cycle cost projection (based on 1998 values) equals about $10 million.

By comparison, the four fuel cells consume 7,800 standard cubic feet per hour of natural gas, while producing 2.8 million BTU/hour of hot water and 740 kW of electricity (340 kW critical and 400 kW non-critical). The fuel cells do not require conditioned space or special environments. The value of the heat supplied by the fuel cell is estimated annually at about $107,000. Annual operating and installation costs average $630,000 per year; 20-year life cycle cost projection (based on 1998 values) is calculated at $9.8 million.

NATURAL GAS USAGE

The natural gas meter at the First Natural Bank of Omaha measures natural gas usage for all four fuel cells in aggregate. There are no individual gas meters on each unit. Dividing the total gas usage for each month by four gives a rough approximation of the gas usage for each fuel cell. Over the course of a year this method should yield fairly accurate numbers.



In the first twelve months of operation the fuel cells used 47,245 Mcf of natural gas. This is approximately 984 Mcf per fuel cell per month. For the first twelve months of operation the fuel cells were operated at 150 kilowatts output because of the high nitrogen content of the natural gas. On June 5, 2000 a nitrogen removal system was installed on the natural gas system at the bank and the kilowatt output of the fuel cells was increased to 200 kilowatts.

THERMAL OUTPUT

The manufacturer (UTC Fuel Cells) installed the "high grade heat" option on all four fuel cells in Omaha. The heat recovered from the fuel cells is <u>not</u> metered; so approximated design loads are used in the heat recovery comparisons in this report. The heating loads were modeled using an energy analysis program.

Excess heat from the fuel cells is removed through an integral heat exchanger on each fuel cell power plant. The captured waste heat, up to 700,000 Btuh per fuel cell, supplements the banks existing heating system. This hot water is used for space conditioning in the winter and for terminal reheat (dehumidification) in the summer. The four fuel cell power plants generate approximately $2.7\text{x}10^6$ BTU per hour for $2.4\text{x}10^{10}$ BTU of heat per year. Of this, it is estimated that approximately $9.5\text{x}10^9$ BTU per year of the heat is recovered. The value of this heat is estimated annually at about $107,000.

The excess heat is also used for snow melting applications. The snowmelt system is used in the patio areas and the walkways on the perimeter of the building. The snowmelt system eliminates the need for snow removal from the secured site.

ENVIRONMENTAL BENEFITS

An independent analysis[3] has determined that the fuel cell based system at the First National Bank of Omaha produces 40% to 50% less greenhouse gases (CO_2) than a traditional UPS (uninterruptible power supply) system that draws its power from the electricity grid.

CERTIFICATION

NORESCO certifies that it has complied in all respects with the grants under DE-FG21-96MC33339, DE-FG21-96MC33340, DE-FG21-96MC33346, and DE-FG21-96MC33348, Climate Change Fuel Cell Program and that the related efforts required by that grant are now fully complete including twelve months of operation and submission of the Final Report herein supplied. Such report is in compliance with the Department of Energy's Special Terms and Conditions for Research Projects Grants for Climate Change Fuel Cell Program.

CONCLUSION

In June of 2000 the four fuel cells at the First National Bank of Omaha successfully completed their first full year of operation. Individual fuel cell operation, performance and associated cost data have met or exceeded all original estimates. The total system operation has performed as designed with no loss of voltage on the critical bus recorded. FNBO now operates one of the premier fuel cell based high availability mission-critical facilities in the world.

The availability of each fuel cell has been more than adequate to support the overall required system availability of 99.9999%. A life cycle cost analysis has shown that the fuel cell based system is more cost effective over the 20-year system life than a traditional UPS system.

In addition to the availability benefits provided by the fuel cell based system the bank has also realized additional operational cost benefits by recovering the thermal energy from the fuel cells.

The success of this project should lead to the adoption of fuel cells for other mission-critical high availability applications.

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Photo 1: Prior to installation in Omaha the entire FNBO system including all four fuel cells were assembled and tested in Middletown, New York. Note – Because natural gas for the fuel cells was not available, compressed natural gas was trucked in using high-pressure tube trailers.

Photo 2: The First National Bank of Omaha fuel cell installation is the largest indoor installation of fuel cells in the world. Photo of fuel cell SN9102 being installed – February 18, 1999.

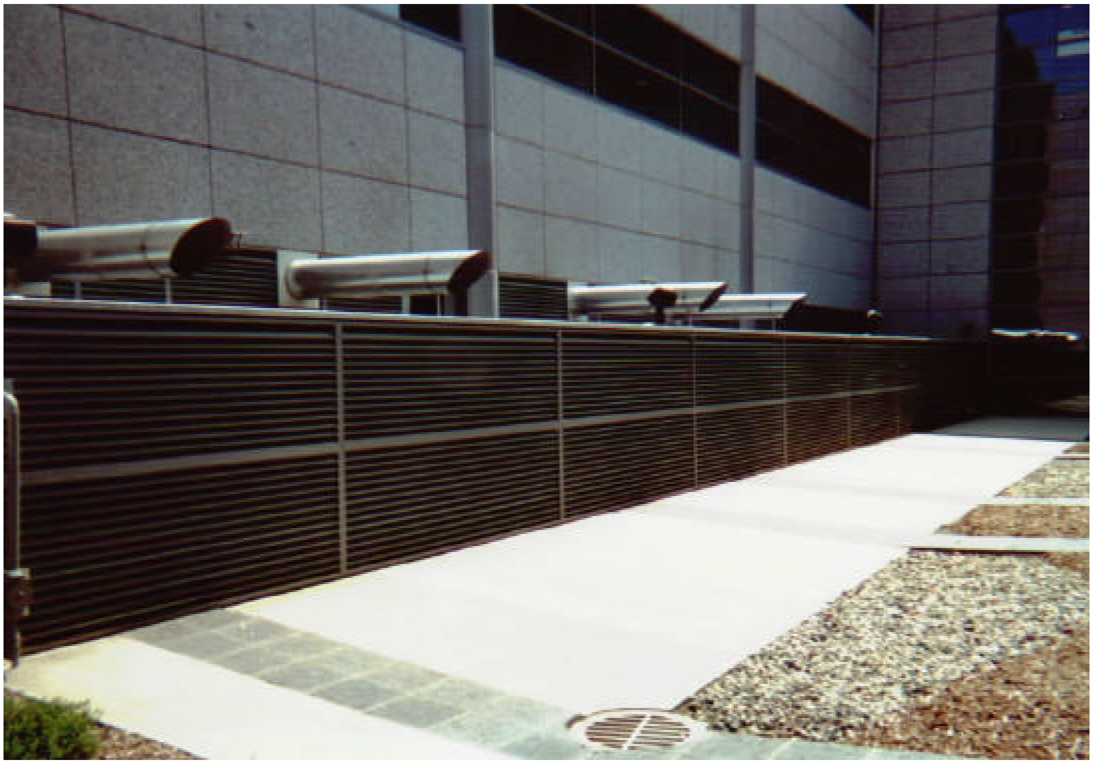

Photo 3: After the fuel cells were installed inside the building the cooling modules were set in place outside the fuel cell room and a louvered enclosure was erected. Vent stacks from the fuel cell exhaust can be seen above the cooling module enclosure.

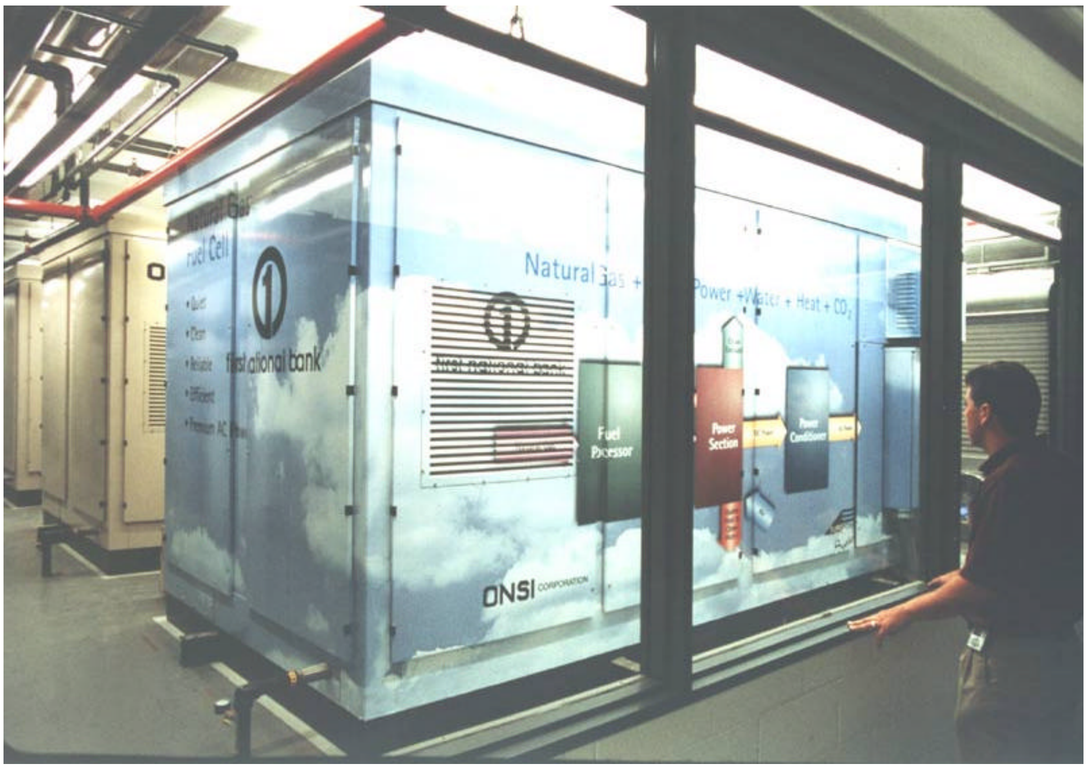

Photo 4: The four fuel cells at FNBO can be viewed from outside the fuel cell room.

[1] Montgomery, D. Bruce, et. Al. (MTechnology, Inc.), Long-term Availability Study of Sure Power System Installation at the First National Technology Center, p.2, 1999

[2] Ditoro, Thomas J., (HDR Architecture, Inc.), Banking on Fuel Cells to Supply Critical Loads - Pure Power Magazine, p. 20, Fall 1998

[3] Romm, Dr. Joseph, (Center for Energy and Climate Solutions), Greenhouse Gas Analysis of the Sure Power System at the First National Bank of Omaha, p. 1, June 1, 1999